



## A SUMMARY OF MPC'S FOR ACCELERATOR

### PRODUCED ACTIVITY IN AIR

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Radiation Physics Note #20

This note is an attempt to clarify the different assumptions used by various authors in their MPC<sub>a</sub> calculations for accelerator-produced radionuclides, and to indicate which MPC is most appropriate for what circumstance.

Most of the accelerator-produced radionuclides which are of interest to us are not listed in either of the two major scientific references (ICRP-2<sup>1</sup> and NBS-69<sup>2</sup>) or in our legally binding reference, the DOE Manual, ch. 0524. The only radionuclides of interest here included in these sources are tritium and <sup>7</sup>Be; I list the MPC<sub>a</sub>'s for them in Tables 1 and 2 for completeness.

In this table, as in those that follow, the dose limits (rem/yr) and hours/week of exposure assumed for each case are listed at the top of each column. The column marked "route" gives the assumed route of exposure for each case. Those values given in each reference are simply entered into the table. The MPC values for cases not given by any author, but which are of interest to us, have been derived by me from the quoted values and placed in parentheses.

This conversion is based on the assumption of a working year of 50 weeks. Thus for conversion from 40 to 168 hours/week for exposure via "submersion" in a radioactive cloud, divide the 40-hour MPC by

$$(365 \times 24) / (50 \times 40) = 4.38$$

In the case of internal exposure via inhalation, one must also allow for half of a person's daily breathing being done in 8 working hours. The conversion from 40 to 168-hour weeks then involves division by

$$(365 \times 16) / (50 \times 40) = 2.92$$

Note that small numerical differences between supposedly identical values occur in these tables; such differences result from different rounding procedures and are not significant.

In these tables the underlined MPC<sub>a</sub> values are those which are the limiting ones for either legal or practical reasons. (In some circumstances these two criteria may conflict!)

Of the various short-lived radionuclides ( $^{11}\text{C}$ ,  $^{13}\text{N}$ ,  $^{15}\text{O}$  and  $^{41}\text{Ar}$ ) produced in air, only  $^{41}\text{Ar}$  is listed in ICRP-2, NBS-69 and DOEM-0524.<sup>3</sup> Because of their short lifetimes the dominant route of exposure for these radionuclides will be external exposure from the surrounding cloud of airborne activity. The formulas given in ICRP-2 for this case take account only of the gamma and/or annihilation photons from these radionuclides, totally ignoring the beta component. The  $^{41}\text{Ar}$  value given in ICRP-2, etc., is thus based only on the dose received from an infinite hemispherical cloud of  $^{41}\text{Ar}$ .

Höfert<sup>4</sup> points out that most practical situations of exposure (e.g., a person working in a beam enclosure) involve a cloud of much smaller than infinite dimensions. ("Infinite" really means large compared to the  $\gamma$  mean free path in air, which is  $\sim 100\text{m}$ .) In these situations the much smaller size of the "cloud" should allow the concentration of the airborne activity to be raised substantially (typically 100x) to compensate for the much reduced  $\gamma$  source volume. However, for small cloud sizes (i.e. comparable to  $\beta$  ranges of several meters in air) the  $\beta$ -dose to the skin is greater than the  $\gamma$  dose to the body as a whole. Thus the  $\beta$  dose to the skin limits the  $\text{MPC}_a$  for small "clouds" to only perhaps only 20 times, rather than 100 times the  $\text{MPC}_a$  for  $\gamma$  exposure from an infinite cloud. The values quoted from Höfert in Tables 1 - 6 are for a 4m radius hemispherical cloud. The quoted values take into account absorption of the  $\beta$ -rays by the dead upper layer of the skin ( $7\text{ mg/cm}^2$ ). For substantially smaller enclosures and cloud radii (e.g., 1m) the calculated  $\text{MPC}_a$ 's only increase by 25-50%. For cloud radii larger than  $\sim 15\text{m}$ , the  $\gamma$  dose rate is greater than that of the  $\beta$ 's, so the  $\gamma$ -based MPC's (i.e. those calculated on the basis of ICRP-2 formulae) must be used.

Tables 3-6 give MPC values calculated by Höfert for the  $\beta$ -dominated "small cloud" situation and for the  $\gamma$  dominated "infinite cloud" model. Tables 3-5 also give two values for internal exposure: one for soluble radionuclides (exposure to the total body) and one for insoluble radionuclides resulting only in local exposure to the lung.<sup>5</sup>

The underlined values in all of these tables correspond to the cases most likely to occur at Fermilab. For the four short-lived radionuclides, these are  $\beta$ -exposure to radiation workers inside a small enclosure, and  $\gamma$ -exposure to the general population living inside a large plume down-wind of one of our stacks. These underlined MPC's are similar to those given by Goebel in the CERN report, "Radiation Problems Encountered-The Design of Multi-GeV Research Facilities."<sup>6</sup>

TABLE 5

MPC<sub>air</sub> for <sup>150</sup>Units of  $\mu\text{Ci}/\text{m}^3 = \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE	REM/YR HRS/WK	5 40	5 168	0.5 168	0.17 168
Yamaguchi	SOL (Tot. Body) INSOL (Lung) SUB- $\gamma$ , $R=\infty$		1300 460 1.9	460 160 0.43		
Höfert	SUB- $\gamma$ , $R=\infty$ SUB- $\beta$ , $R=4\text{m}$		2.0 <u>27.</u>			(0.015)

TABLE 6

MPC<sub>air</sub> for <sup>41</sup>ArUnits of  $\mu\text{Ci}/\text{m}^3 = \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE	REM/YR HRS/WK	5 40	5 168	0.5 168	0.17 168
ICRP-2 NBS-69 DOEM-0524	$\gamma$ -SUB, $R=\infty$		2.	0.4	0.04*	(0.013)
Höfert	$\gamma$ -SUB, $R=\infty$ $\beta$ -SUB, $R=4\text{m}$		2. <u>47</u>			(0.015)

\*see footnote 3.

## REFERENCES AND NOTES

1. "Permissible Dose for Internal Radiation", ICRP Publication 2; Pergamon Press, 1959.
2. "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure", National Bureau of Standards Handbook 69, 1959.
3. Most recent version of the ERDA (now DOE) manual, chapter 0524 Appendix.  
  
Note that there is a typographical error in the exponent for the  $^{41}\text{Ar}$  entry for air, 168 hr. week.
4. M. Höfert, "Radiation Hazard of Induced Activity in Air as Produced By High Energy Accelerators". Proc. of the "Second Int'l Conf. on Accel. Dosimetry and Experience". SLAC, Stanford, Calif., Nov. 1969. (Published by USAEC.)
5. C. Yamaguchi, Health Physics 29 393(1975).
6. K. Goebel, editor, CERN 71-21 (1971).

TABLE 1

MPC<sub>a</sub> Values for Tritium (<sup>3</sup>H).Units of  $\mu\text{Ci}/\text{m}^3 \equiv \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE	REM/YR HRS/WK	5	5	0.5	0.17
			40	168	168	168
ICRP-2	SOL		5	2		
NBS-69	SOL		20	5		
DOEM-0524	SOL		<u>5</u>		0.2	<u>(0.06)</u>

TABLE 2

MPC<sub>a</sub> Values for <sup>7</sup>BeUnits of  $\mu\text{Ci}/\text{m}^3 = \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE	REM/YR HRS/WK	5	5	0.5	0.17
			40	168	168	168
ICRP II, NCRP-69 DOEM-0524 }:	SOL		6	2	0.2	(0.07)
	INSOL		<u>1</u>	0.4	0.04	<u>(0.013)</u>

TABLE 3

MPC<sub>air</sub> for  $^{11}\text{C}$ Units of  $\mu\text{Ci}/\text{m}^3 = \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE \ REM/YR HRS/WK	5 40	5 168	0.5 168	0.17 168
Yamaguchi	SOL(Tot.Body) INSOL(Lung) SUB- $\gamma$ , $R=\infty$	180 70 2.5	62 24 0.58		
Höfert	SUB- $\gamma$ , $R=\infty$ SUB- $\beta$ , $R=4\text{m}$	2.6 <u>59</u>			<u>(0.02)</u>

TABLE 4

MPC<sub>air</sub> for  $^{13}\text{N}$ Units of  $\mu\text{Ci}/\text{m}^3 = \text{pCi}/\text{cm}^3$ 

REFERENCE	ROUTE \ REM/YR HRS/WK	5 40	5 168	0.5 168	0.17 168
Yamaguchi	SOL(Tot.Body) INSOL(Lung) SUB- $\gamma$ , $R=\infty$	310. 130. 2.1	110 43 0.47		
Höfert	SUB- $\gamma$ , $R=\infty$ SUB- $\beta$ , $R=4\text{m}$	2.3 <u>41.</u>			<u>(0.017)</u>